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Besides water, P and nitrogen (N) are key limiting resources explaining the yield gap at the global scale. However, estimates of the contribution of each nutrient alone and together (PxN) to the global yield gap are currently lacking. Previous studies are either based on statistical approaches without distinction between P and N (Mueller et al. 2012) or are process-based but consider only one nutrient (Kvakić et al. 2018). Here we assess how much P, N and PxN limits maize, wheat and rice at the global scale through a process-based and spatially explicit modeling approach. We also investigate if the co-limitation is as frequent as found in natural ecosystems (Harpole et al. 2011). To do so, we confronted the nutrient demand (based on C:nutrient ratio and plant organs simulated by a global crop model without stress) and supply (potential P root uptake or N soil input) for each nutrient taken independently. The magnitude of the limitation in P and N is expressed through a supply:demand ratio (R_P and R_N respectively). Then, the effect of the interaction between P and N on the productivity is represented by two formalisms: based on the Liebig law of minimum or the multiple limitation hypothesis, leading to the computation of a supply:demand ratio R_{NP}.
We found that the N and P limitations are of the same order of magnitude at the global scale for each nutrient (R_N~R_P~0.5), but with strong spatial heterogeneity (Figure 1). When considering N and P together, the supply:demand ratio (R_{NP}) reaches 0.3. Increasing R_{NP} to 0.7 requires an increase in N supply of 40-50% and in P supply of 30-35%. The choice of interaction formalism has almost no effect on the current nutrient limitation but a larger effect on the supply increase required to increase R_{NP}. Finally, we estimated that a real co-limitation occurs in ~50% of the crop area. While our study neglects plant adjustment to nutrient limitation (e.g. change in shoot:root ratio), it improves our understanding of the nutrient limitation in cropland and would also contribute to a better nutrient management at the global scale.

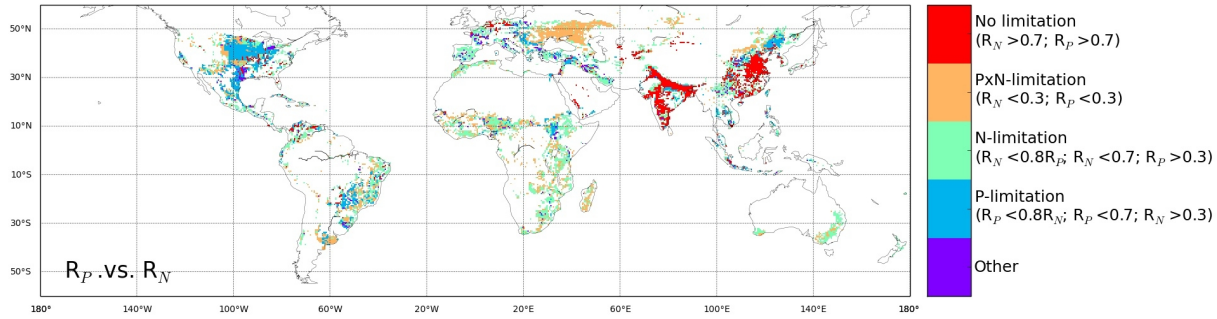

Figure 1: Spatial distribution of the nutrient limitation when N and P are considered independently.

Keywords
interaction phosphorus x nitrogen, nutrient limitation, cropland

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